An exceptionally thick upper Proterozoic (Sturtian) glacial succession in the Mount Painter area, South Australia

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ABSTRACT

The Yudnamutana Subgroup is a thick succession of upper Proterozoic (Sturtian) glacigenic rocks preserved in the Yudnamutana trough in the northeastern part of the Adelaide "geosyncline." In ascending order, the subgroup comprises the Fitton, Bolla Bollana, and Lyndhurst Formations. The name "Hamilton Creek Member" is proposed for a locally developed conglomeratic facies at the base of the Fitton Formation.

These rocks are interpreted as the products of two glacial advances. The first is evidenced by the Hamilton Creek Member, which includes sediment gravity flows derived from subaqueous glacial outwash. The Fitton Formation is composed mainly of basinal siltstones and mudstones with associated coarser-grained rocks that are largely sediment gravity flows. Diamictites in the upper part of the formation signify the onset of a second glacial advance. Thick diamictites of the Bolla Bollana Formation are interpreted as rainout deposits from floating ice derived from ice streams debouching from a steep and high hinterland into a fault-controlled basin. The Lyndhurst Formation is mainly fine-grained rocks. Dropstones and sparse diamictites attest to the presence of some floating ice, but some of the diamictites are probably mass-flow deposits. Paleocurrent data from the Yudnamutana Subgroup indicate transport to the west-northwest. The Sturtian glacigenic rocks are overlain by a transgressive shale.

Stratigraphic similarities exist between the Yudnamutana Subgroup and thinner successions to the west. These stratigraphic similarities probably reflect paleoclimatic changes. The twice-repeated sequence of diamictite followed by mudstone is attributed to two glacial advance-retreat cycles. Local variations in thickness and stratigraphic succession are probably related to contemporaneous faulting.

INTRODUCTION

The Yudnamutana Subgroup (Thomson and others, 1964) was defined in the area north of Mount Painter to include the older of two Sturtian glacigenic successions in the northern part of the Adelaide "geosyncline" (Fig. 1). This region may have been part of a small basin (North Flinders basin) separate from the main Adelaide "geosyncline" (Coats, 1981; Young and Gostin, 1988). Previous research into the stratigraphy of this area is summarized by Preiss (1987). The subgroup (Fig. 2) includes, in ascending order, the Fitton Formation, Bolla Bollana Formation (Bolla Bollana Tillite of Thomson and others, 1976, and Coats, 1981), and the Lyndhurst Formation. These rocks are the basal part of the Umberatana Group (Fig. 2). They lie with low-angle unconformity or nonconformity on rocks of the Burra Group, Callana Group, and crystalline basement of the older Precambrian. The Yudnamutana Subgroup is older than about 750 ± 50 m.y., as indicated by a Rb-Sr isochron age from shale of the overlying Tapley Hill Formation (Webb and others, 1983), and younger than 802 ± 10 m.y., a U-Pb age on zircon from a tuff in the lower part of the Callana Group (Fanning and others, 1986).

The Yudnamutana Subgroup was reported to be as much as 5,000 m thick (Coats, 1981). The section measured for this study is just over 3,000 m thick; much of this discrepancy is due to greater thickness of the Fitton Formation in areas to the northeast (Coats and others, 1969; Coats, 1981). The Yudnamutana Subgroup is one of the thickest accumulations of glacigenic rocks in the world. This paper describes some sections through the Yudnamutana Subgroup in the vicinity of MacDonnell Creek (Fig. 3) at the southwest end of the Yudnamutana trough (Preiss, 1987; Young and Gostin, 1988). In the central and eastern parts of the Yudnamutana trough, conglomeratic facies are locally developed at the base of the mudstone-dominated Fitton Formation (Coats and others, 1969; Coats, 1981).

FITTON FORMATION

Basal Conglomeratic Facies (Hamilton Creek Member)

The name "Hamilton Creek Member" is proposed for the basal conglomeratic facies of the Fitton Formation. The following description is from the Hamilton Creek area (section 1, Fig. 3), where the member is about 350 m thick and lies with sharp nonconformable contact on the Terrapina granite.

The section at Hamilton Creek is shown in Figure 4, together with a more detailed representation of the basal 80 m. The succession consists mainly of laminated silty mudstone interbedded with granule to boulder conglomerates with some sandstone beds. The conglomerates range from a few centimeters to 20 m in thickness. They are mostly massive, but some show crude stratification, particularly in the basal part. Sandy orthoconglomerates dominate, but diamictites are also present and in the lower part of the unit contain abundant granite clasts as much as 50 cm across, in a gray sericitic schistose matrix (Fig. 5). Some sandy orthoconglomerates are graded. Clasts are mainly locally derived granite, but quartz and mafic clasts were also noted. Some conglomerates weather white owing to the incorporation of a high percentage of granules and pebbles of feldspar, derived from the Terrapina granite. One such conglomerate has clasts projecting upward from its upper surface (Fig. 4). About half of the measured section consists of gray-to-olive laminated silty mudstones. The mudstones are commonly interbedded with thin layers of sandstone and granule-to-pebble conglomerate. Rare ripple cross-laminations (Fig. 6) are present. In the middle portion of the measured section, much of the mudstone is slumped (Fig. 4). Isolated clasts (dropstones?) were noted only in

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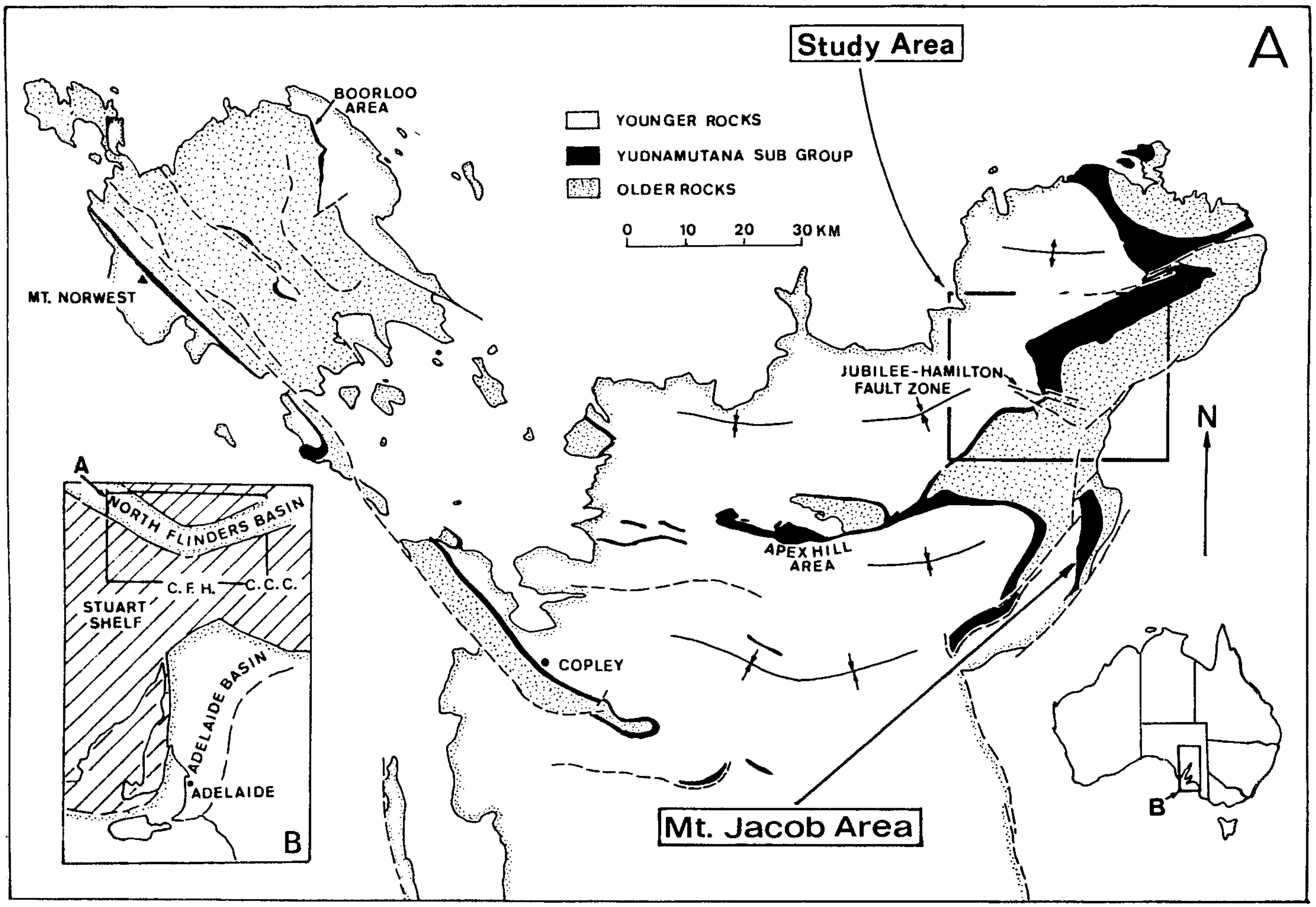

Figure 1. Sketch map of the northern part of the Adelaide "geosyncline" (after Preiss, 1983) to show the location of the study area. Generalized geology of the North Flinders basin is shown.

the uppermost part of the Hamilton Creek Member (Fig. 4). In some parts of the measured section, there is a suggestion of coarsening- and thickening-upward sequences (Fig. 4).

The laminated silty mudstones are considered to represent "background" sedimentation in this basin. Ripple cross-laminations indicate rare traction currents. Influx of coarser-grained material represents episodic sediment gravity flows. This interpretation is favored by the presence of abundant graded conglomerates. Upward-projecting clasts in some conglomerates (Middleton and Hampton, 1973) suggest deposition from viscous mass flows. Slope instability is also indicated by the presence of

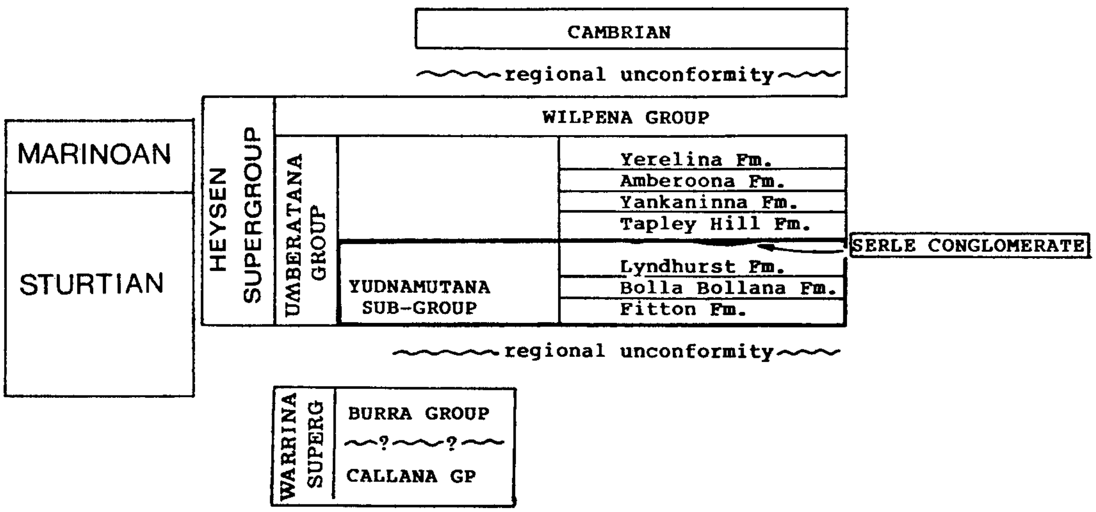

Figure 2. Generalized stratigraphic succession of the upper Proterozoic of the Adelaide geosyncline (after Preiss, 1982) to show the position of the Yudnamutana Subgroup.

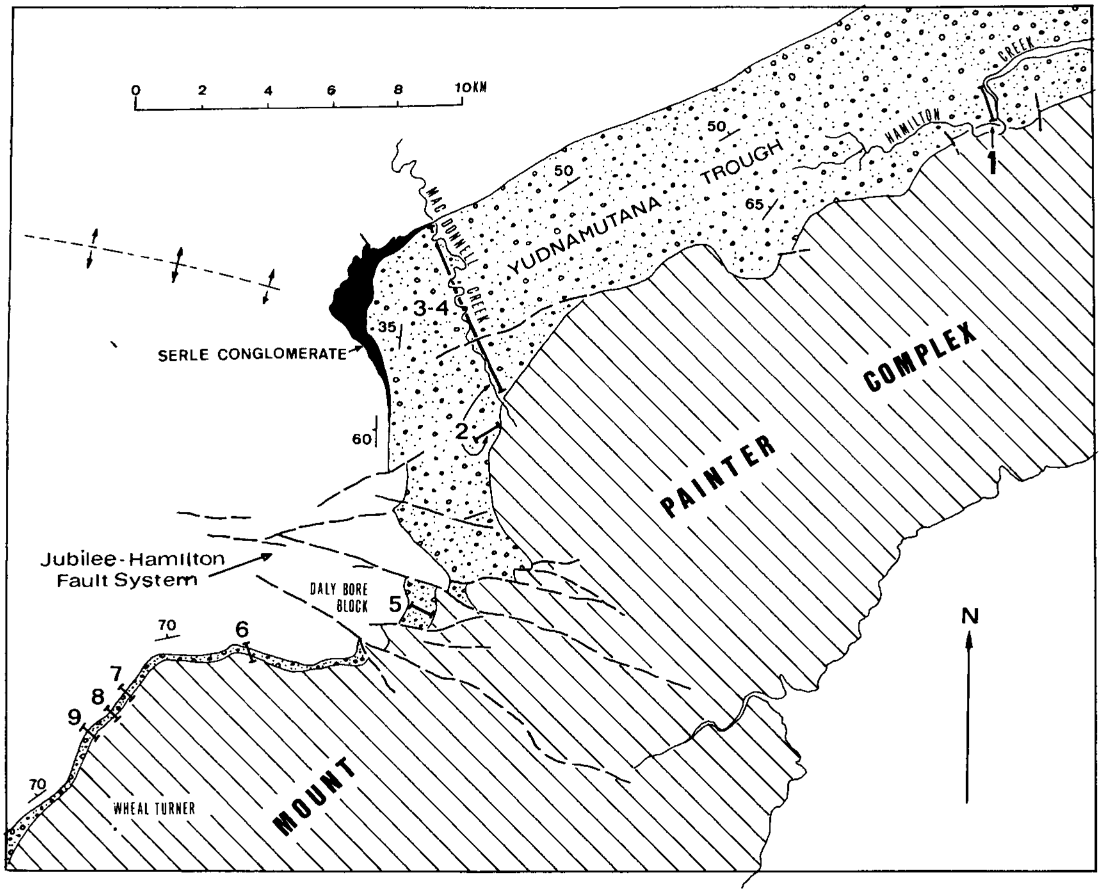

Figure 3. Geologic sketch map (after Coats and others, 1969) to show the Yudnamutana Subgroup (stippled ornament) and Serle Conglomerate in the study area. See Figure 1 for regional location. Note great increase in thickness of Yudnamutana Subgroup across the Jubilee-Hamilton fault system. Location of measured sections discussed in the text are also shown.

highly slumped mudstone units. The presence of floating ice, however, is suggested by the occurrence of dropstones in mudstones in the upper part of the member.

The essentially monomict nature of the conglomerates suggests a local provenance from the underlying granites. It is unusual for such monomict conglomerates and sandstones to be so rich in feldspar (Pettijohn, 1957, p. 256–257). These peculiar sediments may have formed as a result of a frigid climate which would have inhibited feldspar weathering. Many sandy orthoconglomerates and sandstones were apparently emplaced as sediment gravity flows, but the coarse unweathered material probably originated as glacial outwash. A coarsening- and thickening-upward sequence in the upper part of the section (Fig. 4) may indicate progradation of a small lobe in the suprafan portion of a submarine fan (Walker, 1984). Resedimentation processes and slope instability could have been initiated in response to contemporaneous fault activity at the time of deposition of the Yudnamutana Subgroup.

The Hamilton Creek Member is a succession of laminated mudstones formed in a relatively quiet (deep water?) environment into which coarser sediments were introduced by debris flows and turbidity currents. The coarse clastic debris could have achieved some degree of sorting owing to the action of glacial outwash streams. If this interpretation is correct, then the glaciers were probably grounded and were temperate or subarctic. The outwash material was subsequently shed into deeper-water environments, owing to oversteepening of depositional slopes or to seismic shock.

Laminated Mudstone Facies of the Fitton Formation

The laminated mudstone facies was examined mainly in a section in the vicinity of MacDonnell Creek (Fig. 3), where it was found to be about 1,100 m thick (Fig. 7). Previously, Coats (1981) described the Fitton Formation as being 1,625 m thick, but the section examined for this study represents only the upper portion. The unit thins owing to onlap at the southwestern margin of the Yudnamutana trough (Coats, 1981). Belperio (1973) measured a section in the same locality at MacDonnell Creek and recorded a thickness of about 430 m. He divided it into three units, based largely on the presence of metamorphic mineral assemblages. Belperio (1973) and Coats (1981) included what is herein regarded as the upper part of the Fitton Formation in the Bolla Bollana Formation. The Bolla Bollana Formation is herein restricted to the portion of the Yudnamutana Subgroup characterized by thick, crudely stratified diamictites. Diamictites occur throughout the entire thickness of the Yudnamutana Subgroup, and both the base and the top of the Bolla Bollana Formation are gradational in the sense that diamictites are interbedded with finer-grained rocks in the contact zones (Fig. 7). Thus, the simplest definition of the Bolla Bollana Formation in this section is as a diamictite-dominated unit.

The measured section consists mainly of laminated silty mudstones that contain abundant metamorphic scapolite, probably reflecting the original calcareous nature of the muds. Thin diamictites are scattered throughout the succession. Quartzites are the most obvious clasts in these diamictites, but they also contain fragments of granite and porphyritic granite. Sandstone units as much as 10 m thick are present in the lower half of the section but most are much thinner. Thin graded conglomerates and sandstones are common in the upper part of the section (Fig. 7). Some of these contain abundant rip-up clasts of mudstone. Partial and complete Bouma sequences are common. The upper half of the Fitton Formation in this area is characterized by the increase in abundance and thickness of diamictites (as much as 30 m thick), interbedded with laminated mudstones and thin beds of coarser-grained materials, showing evidence of deposition as sediment gravity flows. The top of the Fitton Formation is taken at the appearance of a virtually continuous succession of thick diamictites, which are assigned to the Bolla Bollana Formation.

The Fitton Formation in this area is interpreted as a succession of

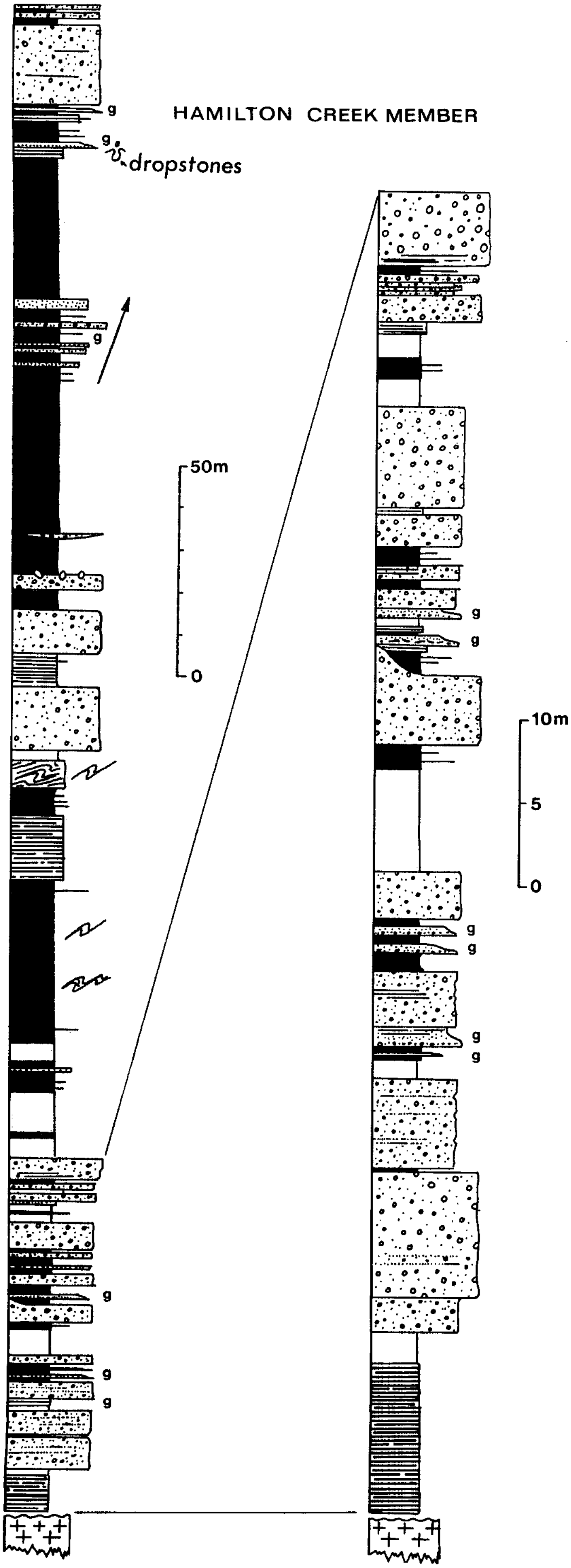

Figure 4. Measured section of the Hamilton Creek Member at the base of the Fitton Formation at Hamilton Creek. See Figure 3 for location of the section (1). Right-hand column shows a more detailed version of the lower part of the succession. See text for discussion.

Figure 5. Cleaved diamictite with abundant granite clasts in the basal part of the Fitton Formation (Hamilton Creek Member) at Hamilton Creek.

Figure 6. Small-scale cross-bedding in fining-upward sequence in the Hamilton Creek Member (lower part of the Fitton Formation) at Hamilton Creek. Broken fragment below hammer shows diamictite with metamorphic reaction rims (light) around clasts.

relatively deep-water muds. Into this environment from time to time, there was an influx of coarser material, introduced as sediment gravity flows. Thin diamictites may have formed as mass flows or as rainout from floating ice. The latter interpretation is suggested by the presence of abundant dropstones in the upper half of the section. The lower portion of the measured section is interpreted as having formed in a period of glacial recession. These rocks contrast with the coarse-grained units at the base of the formation, interpreted as resedimented glacial outwash debris, formed in a relatively proximal setting *vis à vis* the ice front. The appearance of thick diamictites, interpreted as having formed by rainout from floating ice (Eyles and others, 1985) suggests initiation of a second ice advance into the depositional basin.

BOLLA BOLLANA FORMATION

This unit has a gradational contact with the underlying Fitton Formation. It is about 1,000 m in thickness in the measured section (Figs. 3 and 8). Much greater thicknesses estimated by Coats (1981) probably reflect, in part, inclusion of gradational units herein assigned to the other formations.

Interbeds in the diamictite form a minor portion (5%–10%) of the formation. They are mostly laminated silty mudstones. The mudstones and siltstones are commonly associated with thin beds of granule-to-pebble conglomerate and thin diamictite layers. Some contain partial Bouma sequences. Slumped bedding is fairly common in these fine-grained intervals, as also are dropstones.

Coarse-grained rock types include sandstones, some of which are pebbly and display graded bedding. The larger clasts are commonly scattered or "floating" in these sandstones. Near the top of the formation, there are several lenticular bodies of feldspathic sandstone, a few meters thick and hundreds of meters wide. Some of the sandstones contain boulders of quartzite as much as 1 m in diameter. Granule conglomerates and densely packed pebble conglomerates are also present.

Diamictites are predominant and occur as beds ranging from a few centimeters to units more than 100 m thick. They are mostly pebbly diamictites, but many contain scattered larger clasts (as much as 1 m diameter) which are commonly gray or white quartzite. Fragments of granitic quartz porphyry, schist, gneiss, and mafic plutonic igneous rocks were also noted. Some diamictites also contain locally derived mudstone clasts. Striated clasts are rare.

The matrix of the diamictites is variable; it is mostly a fine-grained silty mudstone, but some varieties are sandy and others dolomitic. Two orange-weathering dolomitic diamictites were noted in the upper part of the formation (Figs. 8 and 9). Some diamictites are massive, but most are characterized by some stratification, either in the form of silty interbeds or expressed as crude stratification, related to differences in matrix texture/composition. In some outcrops, there is a bedding-parallel cleavage that simulates bedding.

The Bolla Bollana Formation consists mainly of diamictites, a rock type that is notoriously difficult to interpret (Schermerhorn, 1974; Dreimanis and Schlüchter, 1985). Much of the interpretation must consequently derive from associated strata, which provide clues as to the depositional setting. The Bolla Bollana Formation is particularly enigmatic because of the dearth of associated stratified rocks. The presence of laminated mudstones, associated with coarser-grained beds displaying evidence of sediment-gravity-flow processes, suggests a a relatively deep-water environment. The common occurrence of dropstones indicates the presence of floating ice. The near-ubiquitous stratification in the diamictites themselves indicates that they were probably formed in water. These diamictites are interpreted as the product of sedimentation from glaciers that extended out into a marine(?) basin where faulting and/or steep slopes led to resedimentation. Some of the better-sorted rocks may have formed by resedimentation of diamictites (Wright and Anderson, 1982). The precise depositional mechanism for such a thick accumulation of diamictites remains obscure. Some (for example, Drewry and Cooper, 1981) have suggested, by analogy with present-day marine glaciation, that deposition from sea-going glaciers occurs mainly at the grounding line and that a thick accumulation of diamictites is possible only where there is rapid oscillation of the grounding line (Eisbacher, 1985). Because of the general absence of other criteria of ice marginal deposition, such as outwash deposits, and evidence of erosion by ice advance, this theory is discarded in favor of rainout from floating ice (Eyles and others, 1985), possibly from rapidly calving icebergs derived from wet-based tidewater glaciers, similar to those invoked by Barrett (1981) to explain the thick and extensive diamictite-rich upper Cenozoic succession in the Ross Sea region of Antarctica. The abundance and thickness of vaguely stratified diamictites suggest that rainout from sediment-charged glacial ice was the predominant depositional process. The mechanism whereby such a sediment-charged ice mass could be formed and maintained remains uncertain. Rates of deposition in such a regime can be very rapid. Barrett (1981) suggested about 50 m per million years for the upper Cenozoic marine glacial deposits of the Ross Sea area and much faster rates (as much as 500 m per million years) were listed by Edwards (1978, p. 435). Regional studies (Coats and others, 1969; Coats, 1981) show that deposition of the Yudnamutana Subgroup took place during a period of active faulting. This may have provided a mechanism to form and maintain a steep topographic profile in the source area and the subsident depositional basin required to accommodate the large amounts of sediment introduced by glaciers. Such conditions, during a glaciation, could have led to particularly rapid rates of ice advance. Abundant sediment-charged icebergs and possibly ice shelves, fed by rapidly moving ice streams (Anderson and others, 1983), could have been maintained for periods of a few million years. Trapping of large amounts of floating ice in the proposed rift basin could also have been significant in the deposition of such thick diamictite-rich successions.

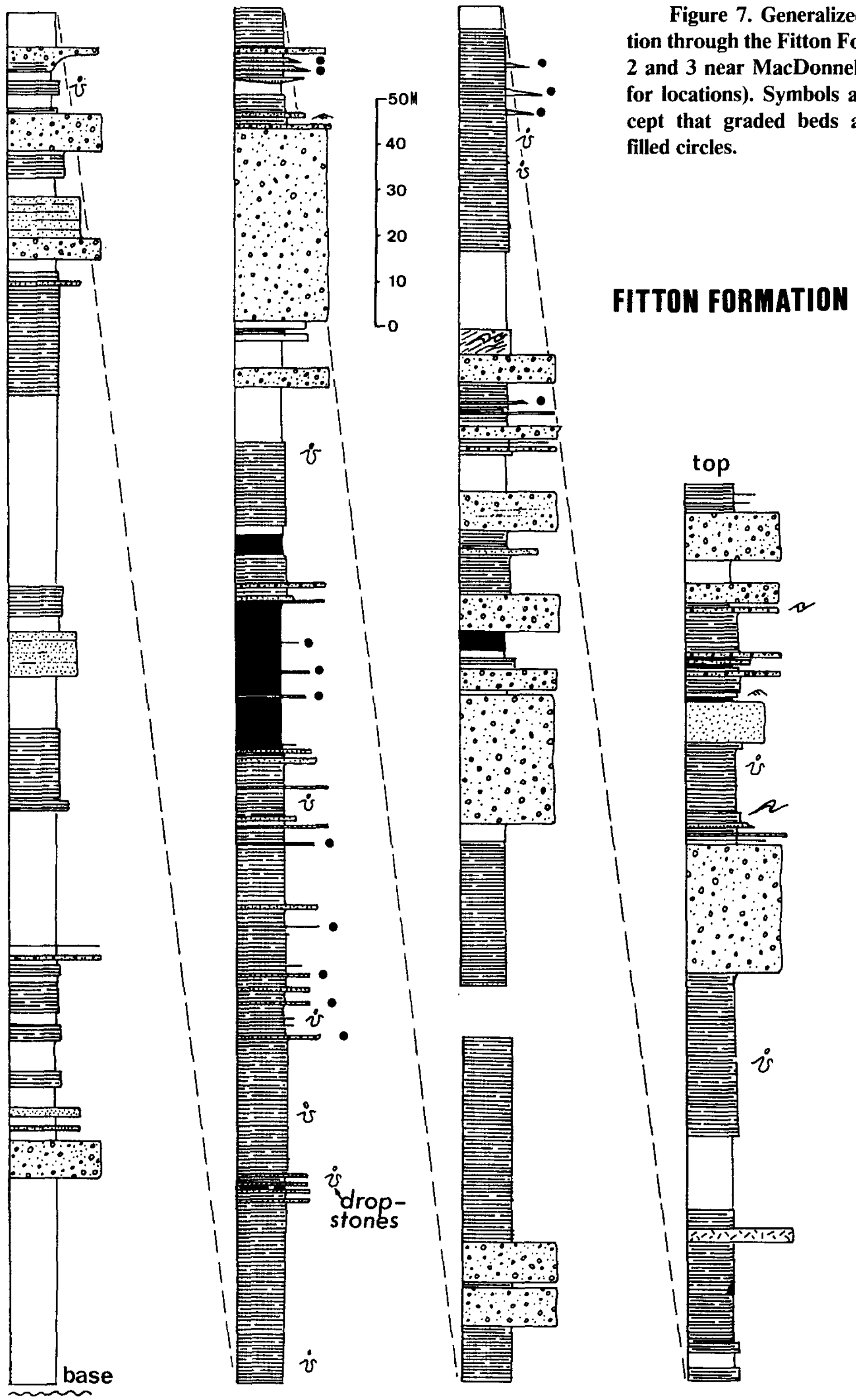

Figure 7. Generalized stratigraphic section through the Fitton Formation at sections 2 and 3 near MacDonnell Creek (see Fig. 3 for locations). Symbols as for Figure 4, except that graded beds are represented by filled circles.

LYNDHURST FORMATION

The Lyndhurst Formation is considered to be restricted to the region of the Yudnamutana trough (Coats and others, 1969). It has an asymmetric lenticular profile, with thickest development in the southern part of the trough. It was assigned a thickness of 960 m by Coats (1981). The section measured for this study is about 1,200 m thick (Fig. 10), but possibly the basal part was included by Coats (1981) in the Bolla Bollana Formation.

The base of the Lyndhurst Formation was picked (Figs. 8 and 10) where the thick diamictites of the Bolla Bollana terminate. The Lyndhurst

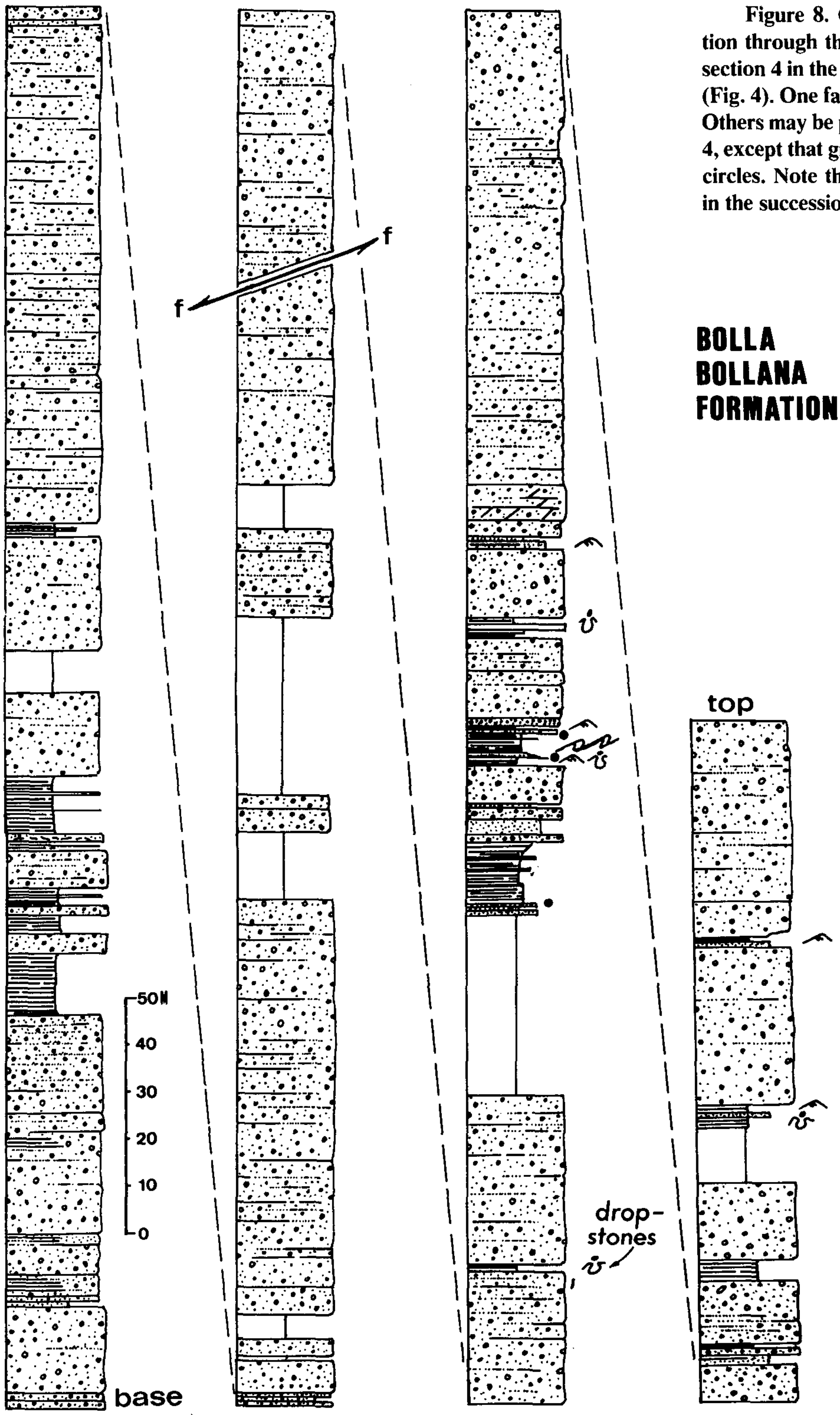

Figure 8. Generalized stratigraphic section through the Bolla Bollana Formation at section 4 in the vicinity of MacDonnell Creek (Fig. 4). One fault is shown in the succession. Others may be present. Symbols as for Figure 4, except that graded beds are shown by filled circles. Note the predominance of diamictite in the succession.

was described by Coats (1981) as consisting of dark blue shale, siltstone, minor sandy carbonate, coarse sandstone, and dolomite. In the measured section, about 75% of the formation was found to be stratified: finely bedded-to-laminated mudstones, silty mudstones, and associated coarser-grained stratified sedimentary rocks. The remainder consists of sparse pebbly diamictites in beds as much as about 20 m thick. These "diamictites" are difficult to identify, owing to the paucity of clasts and bedding-parallel cleavage, which causes them to resemble laminated mudstones.

Stratified Heterogeneous Siltstone-Dominated Facies

Laminated and ripple cross-laminated siltstones (Fig. 11) and silty mudstones constitute the greater part of the Lyndhurst Formation. Sedimentary structures include fine parallel laminations, wavy laminations, graded beds, and partial and complete Bouma sequences. Dropstones both small and large (Fig. 12) are present throughout the Lyndhurst Formation but are especially common in the lower part (Fig. 10). Convoluted beds

Figure 9. Diamictite with recessive dolomitic matrix in the Bolla Bollana Formation at MacDonnell Creek. Location in the third column of Figure 8 is shown by dolomite symbol. Coin is 3 cm in diameter.

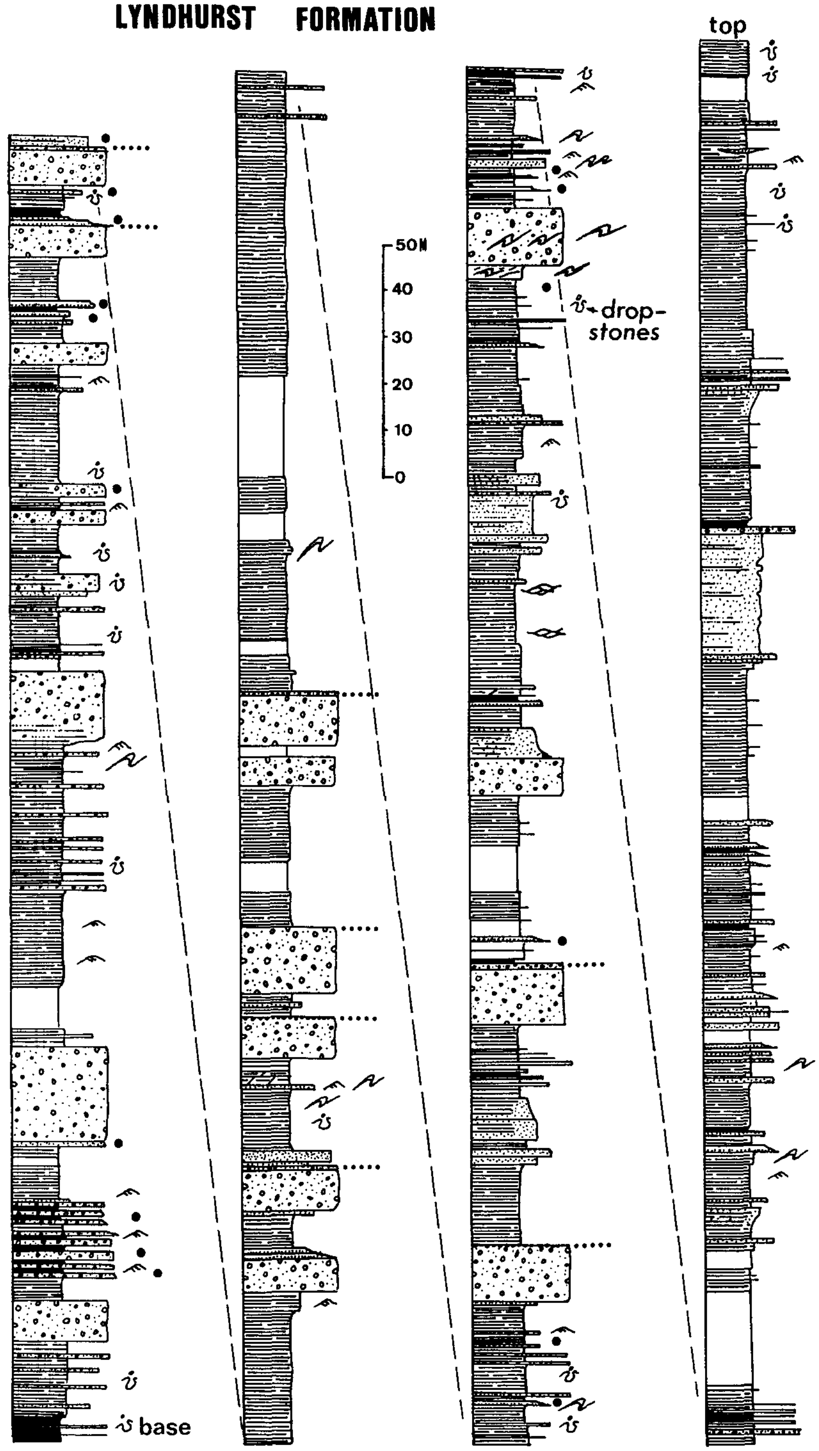

Figure 10. Generalized stratigraphic section through the Lyndhurst Formation in the vicinity of MacDonnell Creek (Fig. 3). Symbols as for Figure 4, except that graded beds are shown by large filled circles. Rows of small black dots above some diamictites represent lag conglomerates.

(Fig. 13) are also common in the fine-grained part of the formation. Some laminated silty mudstones, particularly in the upper part of the unit, weather orange and brown and are probably dolomitic. Sole structures, mainly flute and groove casts, are developed on some of the coarser silty beds and at the bases of interbedded sandstones.

A great variety of coarser-grained sedimentary rocks is interbedded with the siltstones. Apart from the thicker sparse diamictites described below, paraconglomerates in the Lyndhurst Formation are generally less than a meter thick. Some diamictites display inverse to normal grading and may be mass-flow deposits. Some have erosive bases. Other coarse-grained sedimentary rocks include sandstones and granule and pebble conglomerates. These coarser units commonly display graded bedding, and some show complete or partial Bouma sequences (Fig. 14), suggesting deposition by turbidity currents. Rip-up clasts are fairly common, and sole structures are developed on the bases of many beds. About 200 m from the top, one bed of coarse sandy granule conglomerate is in the form of a lens, 10 cm to 3.5 m thick and about 30 m long, probably representing a cross section through a channel fill. It contains many "tear-drop"-shaped rip-up clasts of laminated silty mudstone. In some places, the beds are arranged into coarsening/thickening-upward sequences and thinning/fining-upward sequences on a scale of 10 to 20 m.

The laminated silty mudstones are interpreted to be the "back-

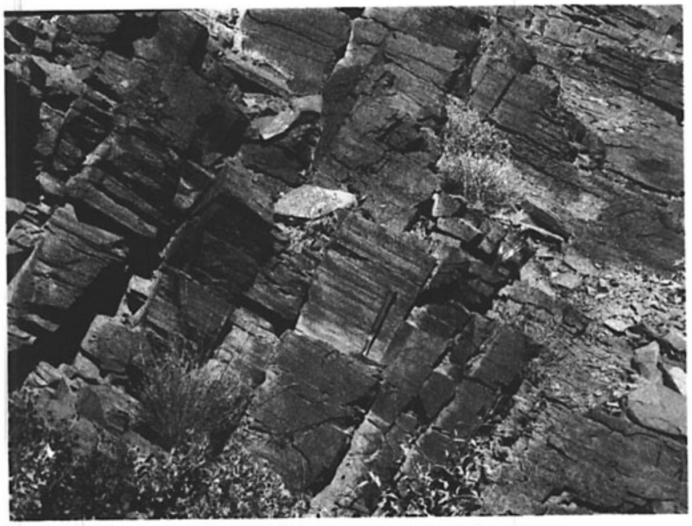

Figure 11. Typical outcrop of laminated silty mudstone of the Lyndhurst Formation at MacDonnell Creek.

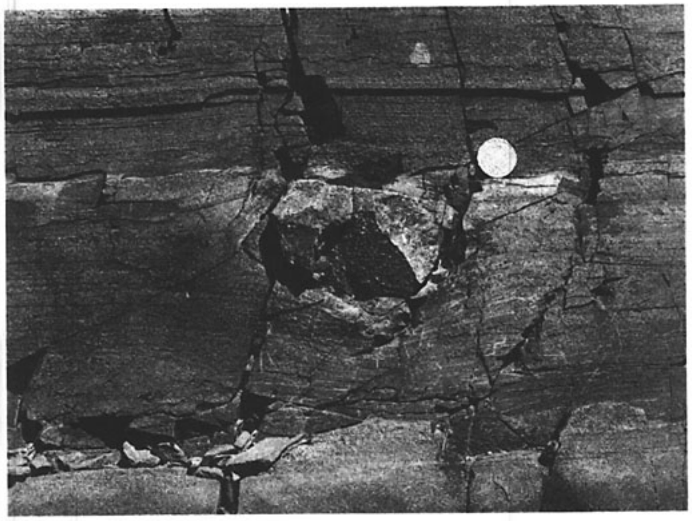

Figure 12. Dropstone in laminated mudstones of the Lyndhurst Formation at MacDonnell Creek. Coin is 2.5 cm in diameter.

ground" sedimentation in the basin, resulting from a combination of suspension deposition and weak traction-current activity. The coarser beds mostly represent the influx of turbidites and other kinds of sediment gravity flows onto the basin floor (Walker, 1984; Mutti and Ricci-Lucchi, 1974). The generally fine-grained nature of the rocks suggests a relatively distal setting. The presence of dropstones, throughout the entire thickness of the formation, attests to the continued presence of debris-laden floating ice (icebergs or shore ice).

Sparse Pebbly Diamictites

Diamictites form a significant portion of the Lyndhurst Formation. They are thickest (10–20 m) and most abundant in the lower part of the formation (Fig. 10). Most of the clasts in the diamictites are pebble sized, but there are some larger quartzite clasts. The matrix is typically a structureless siltstone, but in some cases, internal lamination is visible in the lower portions of diamictites. Some diamictites include convoluted siltstone beds. Many of the diamictites are overlain by a thin layer of pebbles or pebbly sandstone. The upper 300 m of the Lyndhurst Formation contains only thin diamictite layers.

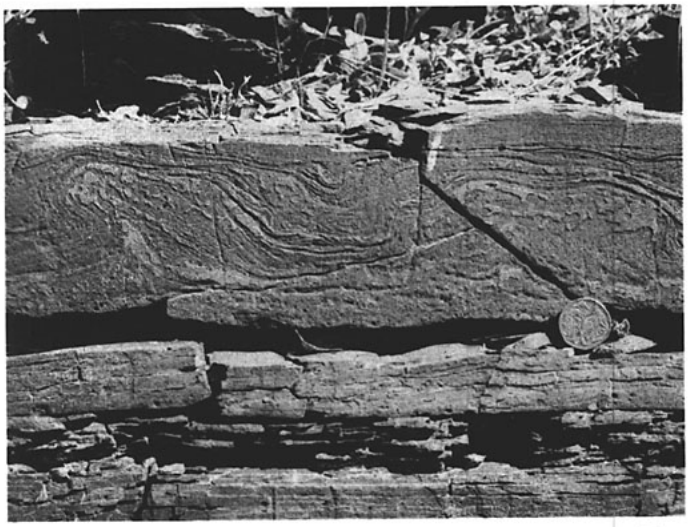

Figure 13. Slumped laminated mudstones in the Lyndhurst Formation at MacDonnell Creek. Note coarse base of bed near coin (2.5 cm diameter).

Interpretation of the sparse pebbly diamictites is difficult. They are associated with a succession that has all the attributes of a turbidite basin, so that it is possible that some of the diamictites are the result of mass flow, incorporating associated silty mudstones to produce the abundant fine-grained matrix material. Alternatively, they could have formed by rainout from icebergs or an ice tongue in a fashion analogous to that suggested for the more massive diamictites of the underlying Bolla Bollana Formation. A similar succession, about 1,300 m thick, was described from upper Cenozoic glaciomarine deposits of the Ross Sea region (Barrett, 1981), where claystones with scattered pebbles occur as units as much as 100 m thick and are interbedded with laminated silty claystones and diatomaceous claystones. The succession is interpreted as having formed from rapidly calving wet-based glacier tongues at the head of the Ross Embayment. A similar depositional environment may be postulated for the Lyndhurst Formation. Dropstones are less abundant in the Lyndhurst Formation than in the upper Cenozoic succession of Antarctica, perhaps indicating that the ice withdrew to the land from time to time, preventing ice rafting (Anderson and others, 1983; Molnia, 1983), or that an ice sheet or a cover of sea ice developed, preventing calving in the same region. Some layering in the basal parts of diamictites may have been produced in the basal zone of "shearing," as proposed by Middleton and Hampton (1973) for debris flows. The common occurrence of pebble concentrations on the upper surfaces of diamictites could also be due to matrix support of larger grains during transport by viscous debris flows but is more likely to be due to bottom currents. Similar concentrations of stones (boulder pavements) have been described by Eyles and others (1985) from the Cenozoic Yakataga Formation in Alaska and by Molnia and Carlson (1978) from the present-day Gulf of Alaska. They ascribed these pavements in part to the action of shelf ice on bottom sediment, but such an origin is considered unlikely in the case of the Lyndhurst Formation because of the lack of additional evidence of the presence of grounded ice. Spencer (1971) described similar conglomerates on the upper surfaces of diamictites of the upper Proterozoic Port Askaig Tillite. He considered the diamictites to be true tillites (Dreimanis and Schlüchter, 1985), deposited

Figure 14. Coarse graded bed overlain by laminated and cross-laminated sandstone, forming part of a Bouma sequence in the Lyndhurst Formation at MacDonnell Creek. See Figure 3 for location of the MacDonnell Creek section.

directly from grounded ice, and explained the pebble concentrations as being due to marine transgression, producing beach gravels. Such an interpretation is incompatible with the relatively deep-water regime suggested by the abundant muddy turbidites of the Lyndhurst Formation. The pebble concentrations on the upper surfaces of diamictites in the Lyndhurst Formation are attributed to reworking by bottom currents during periods of reduced sediment input.

PALEOCURRENTS

No paleocurrent data have previously been published from rocks of the Yudnamutana trough, and there has been considerable speculation as to the paleoslopes and provenance of the Sturtian sediments (Coats, 1981; Belperio, 1973). Directional sedimentary structures are rare in the Yudnamutana Subgroup, but during the course of this study, some paleocurrent data were obtained from all three formations of the subgroup. Most of the data comes from the Lyndhurst Formation, but a few measurements were made in rocks of the Fitton and Bolla Bollana Formations.

The data are shown in Figure 15. They were obtained from a variety of sedimentary structures, including ripple cross-laminations, flute casts, and groove casts. Paleocurrent directions from ripple cross-laminations show a wide scatter but indicate predominant transport to the west. This is in agreement with westerly transport suggested by flute casts and a similar alignment of groove casts. Although it is recognized that paleocurrents do not necessarily indicate paleoslope, the consistency between directions of traction and turbidity currents suggests that the basin slope was toward the west or northwest and that the Sturtian sediments of this area were derived from a hinterland to the east, in the vicinity of the Mount Painter Complex (Fig. 3).

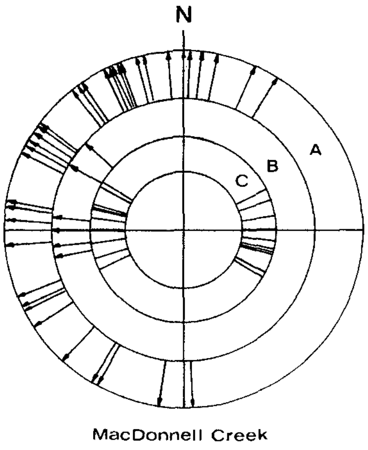

Figure 15. Distribution of paleocurrent directions from structures observed in the MacDonnell Creek section (see Fig. 3 for location). Individual readings are represented except in cases in which two or more structures gave the same azimuth. Arrows show structures with sense. A shows azimuths obtained from ripple cross-laminations; B shows azimuths of flute casts. C shows the orientation of groove casts.

STRATIGRAPHIC RELATIONS WITH ADJACENT AREAS

The great thickness of the Sturtian succession in the Yudnamutana trough, in relation to Sturtian successions elsewhere (Fig. 16), has made correlations difficult. On the 1:125,000 map of the Mount Painter area, Coats and others (1969) correlated the Sturtian of the Yudnamutana trough with rocks to the west and south. Subsequently, in the 1:250,000 regional map of the Copley area, Coats (1973) considered the thick succession of the Yudnamutana Subgroup to be locally developed and separated by an unconformity from a younger glacigenic sequence represented by the Serle Conglomerate (Fig. 16). The Serle was correlated with virtually all the glacigenic Sturtian rocks to the west and south on the Copley Sheet. This correlation was extended to the southern part of the Adelaide geosyncline, where a similar unconformable relationship was proposed between the Pualco tillite and the Wilyerpa Formation (Forbes and Cooper, 1976; Preiss, 1983). The Serle Conglomerate (Young and Gostin, 1989) has been reinterpreted as the channelized portion of a submarine fan complex. Similar lenticular conglomerates overlie Sturtian glacigenic rocks in an area to the southwest of the Yudnamutana trough (Ashton, 1973; Young and Gostin, 1989). These relationships suggest that the thin glacigenic Sturtian succession to the south and west of the Yudnamutana trough is equivalent to, not younger than, the rocks of the Yudnamutana Subgroup within the trough. Measurement of a number of stratigraphic sections on the southwest side of the Yudnamutana trough (Figs. 3 and 16) illustrates significant thickness changes, but there is a common stratigraphic sequence in the trough and the marginal area.

According to this proposal, the Hamilton Creek Member in the Yudnamutana trough is equivalent to the lowest diamictite sequence to the southwest (Fig. 16) and farther west at Copley, where it has been interpreted as a basal tillite (Young and Gostin, 1988). The basal diamictite is not represented in a fault block near Daly Bore (Fig. 3, section 5; Fig. 16), but this section is located on what was probably the rift shoulder of the Yudnamutana trough and may have been uplifted at that time. The various formations preserved in the Yudnamutana trough (Fig. 16) can be matched to thinner equivalents in areas to the west (Young and Gostin, 1988). The absence of certain units in fault blocks in the vicinity of the rift shoulders (compare to Bjorlykke, 1985; Nystuen, 1985) could reflect "piano key" tectonics, causing these areas to be relatively positive during or after deposition of the Lyndhurst Formation.

CONCLUSIONS

Detailed study of a measured section through the Yudnamutana Subgroup in the MacDonnell Creek area and subsidiary sections at Hamilton Creek and in areas to the southwest of the Yudnamutana trough has

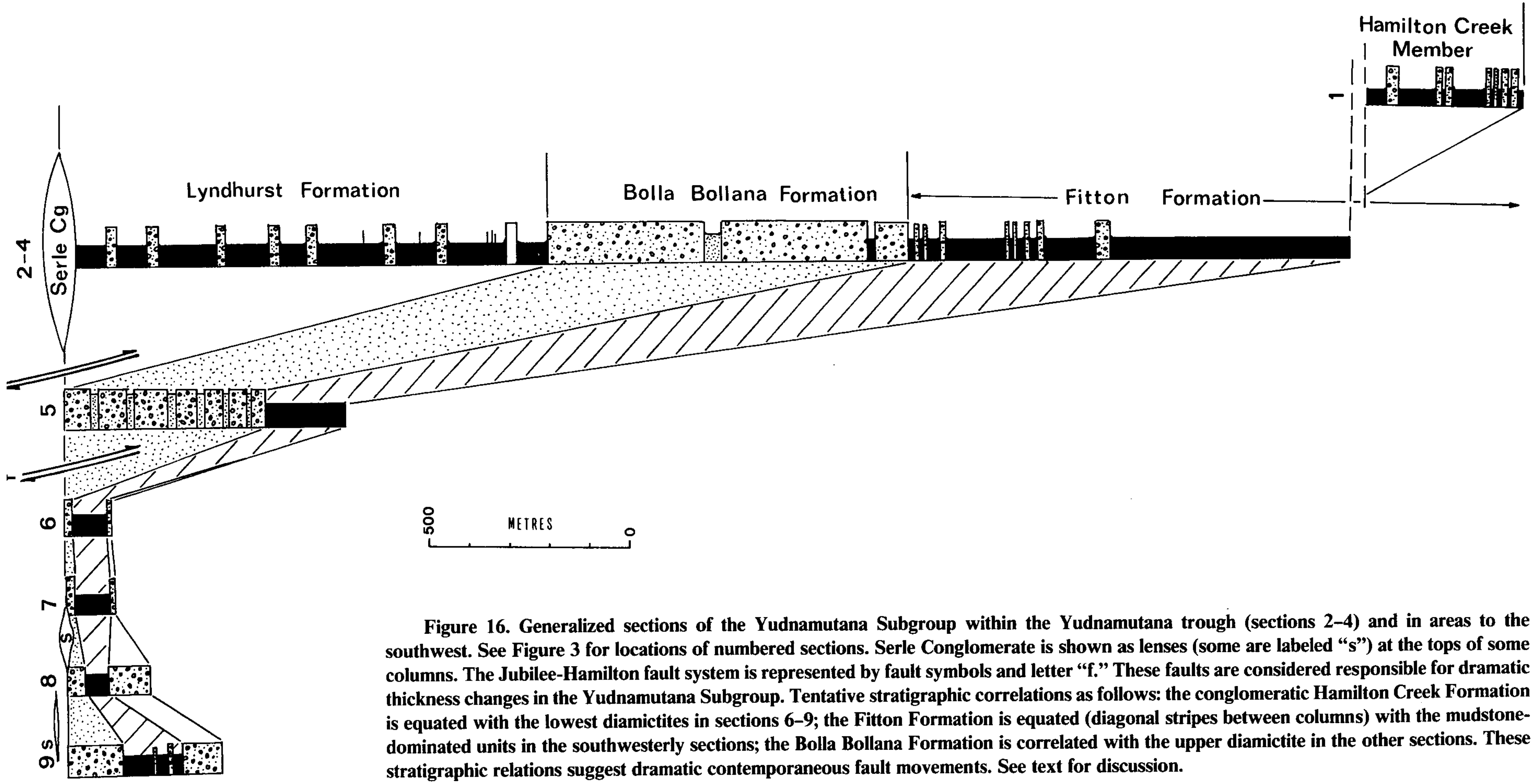

Figure 16. Generalized sections of the Yudnamutana Subgroup within the Yudnamutana trough (sections 2–4) and in areas to the southwest. See Figure 3 for locations of numbered sections. Serle Conglomerate is shown as lenses (some are labeled "s") at the tops of some columns. The Jubilee-Hamilton fault system is represented by fault symbols and letter "f." These faults are considered responsible for dramatic thickness changes in the Yudnamutana Subgroup. Tentative stratigraphic correlations as follows: the conglomeratic Hamilton Creek Formation is equated with the lowest diamictites in sections 6–9; the Fitton Formation is equated (diagonal stripes between columns) with the mudstone-dominated units in the southwesterly sections; the Bolla Bollana Formation is correlated with the upper diamictite in the other sections. These stratigraphic relations suggest dramatic contemporaneous fault movements. See text for discussion.

provided the basis for a depositional model for the Sturtian glacigenic rocks of this region. A locally developed basal conglomeratic unit is named the "Hamilton Creek Member"; the basal Hamilton Creek Member is mostly resedimented ice-margin deposits. The remainder of the Fitton Formation formed during glacial recession (basal fine-grained part) followed by a second glacial advance, during which diamictites formed from floating ice.

The Bolla Bollana Formation is mostly crudely stratified diamictites formed by rainout from floating ice, but sediment gravity flows were also active during deposition.

The Lyndhurst Formation is mostly siltstones and silty mudstones with intermittent sparse pebbly diamictites. Turbidity currents and other sediment gravity flows were active during deposition of this unit. Some diamictites with a silty matrix are interpreted as mass-flow deposits.

Paleocurrent data from both traction currents and sediment gravity flows show a consistent west-northwesterly transport direction, interpreted as the local paleoslope.

The rocks of the Yudnamutana Subgroup are considered to be correlative with much thinner successions to the southwest.

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